DIGITAL SIGNAL PROCESSING LABORATORY

EXPERIMENT-5 - Reconstruction of given signal by power spectral density.

Group:- 32

Authors:-

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Aim:

Reconstruct the signal from the given power spectral density

Theory:

We will reconstruct a signal in this experiment using the power spectral density. We produce random white noise in order to generate a random signal with known power spectral density. White noise has all the frequencies it includes, just like white light has all the frequencies it needs. Hence , white noise's power spectral density is a straight line. Another process with a comparable PSD is the impulse function, however it's exceedingly challenging to reproduce the impulse function in reality. So, we decide white noise at random and run it through the specified filter.

To estimate the Power Spectral Density, we can use any of these two methods:

i) The Welch Non-Parametric Method: Averaging Modified Periodogram
ii) The Yule Walker AR Model: Parametric Method

WELCH NON-PARAMETRIC METHOD:
With this technique, we separate the filtered gaussian white noise signal into several components (8). To provide a more accurate estimate of the power spectral density, we may optionally include a very little overlap of up to 50%.

Then, we determine the PSD of each of the eight sections across a window (often the Hamming window) and take into account their average. These component PSDs are referred to as modified Welch periodograms. The overlap between subparts and windowing of the subparts were added to the standard periodograms to improve estimations.

PARAMETRIC METHOD FOR POWER SPECTRAL ESTIMATION: YULE-WALKER AR METHOD

The auto-correlation functions of the filtered gaussian white noise are all obtained and used in this approach to determine the AR parameters. Then, in order to estimate the PSD, we compute the variance. In our situation, the AR method's order is assumed to be 3.

Observation:

Code-

```
noiseVar = 1.5;

N = 1024;
M = 16;
D = M/2;
L = N/M;
fs = 10000;
noise = wgn(1,N,noiseVar,'linear');
```

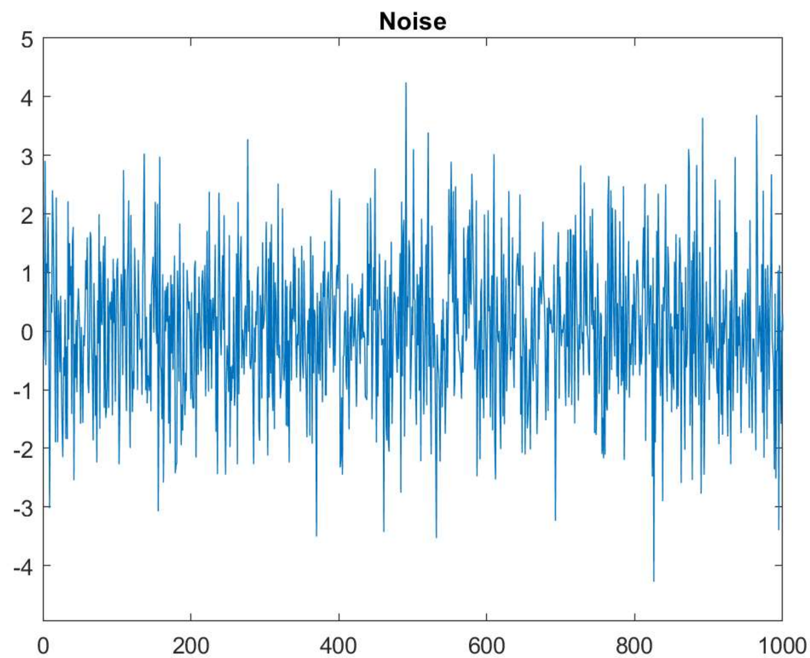
```
plot(noise)

b = 1;
a = [1 -0.9 0.81 -0.729];
x = filter(b,a,noise,[],2);
plot(x)
y = abs(fftshift(fft(x)));
plot(fshift,y);


x_mat = zeros(M,L);
for i = 1:L
   x_mat(:,i) = x((i-1)*(M)+1: i*M);
end

%50% overlapping
L = N/(2*M) -1;
x_mat = zeros(M, L );
for i = 1:L
   x_mat(:,i) = x((i-1)*(M/2)+1: (i+1)*M/2);
end

%hamming window
w = zeros(1,M);
for i=1:M
   w(i)=0.54-0.46*cos((2*pi*i)/(M-1));
end
plot(w);
xlabel('n')
ylabel('w(n)')
xlim([1 M])
title('hamming window')


summation = 0;
for i = 1:M
   summation = summation + w(i)^2;
end
U = (1/M)*summation;

f = -1*(fs/2):fs/M:(fs/2)-1;
P = zeros(length(f), L);
for i=1:L
   sum = 0;
```

```
    for n = 1:M
        sum = sum + x_mat(n, i)*w(n)*exp(-1i*2*pi*f*n/M);
    end
    P(:,i) = (1/(M*U))*(abs(sum).^2);
end

sum2 = 0;
for i = 1:L
    sum2 = sum2 + P(:, i);
end
PSD = (1/L)*sum2;

plot(f, PSD)

p=3;
r = zeros(p+1, 1);
for m = 1:p+1
    sum2 = 0;
    for n = 1:N-m
        sum2 = sum2 + x(n)*x(n+m-1);
    end
    r(m) = (1/N)*sum2;
end
r_mat = zeros(p,p);
for i = 1:p
    for k = 1:p
        r_mat(i, k) = r(abs(i-k)+1);
    end
end

a = -inv(r_mat)*r(2:p+1,1)

summation2 = 0;
for i = 2:p+1
    summation2 = summation2 + a(i-1)*r(i);
end
estimated_variance = r(1) + summation2

f2 = -1*(fs/2):fs/N:(fs/2)-1;
z = exp(1i*2*pi*f2/N)
phase(z)
sum = zeros(1, N);
for k = 1:N
    for i = 1:p
```

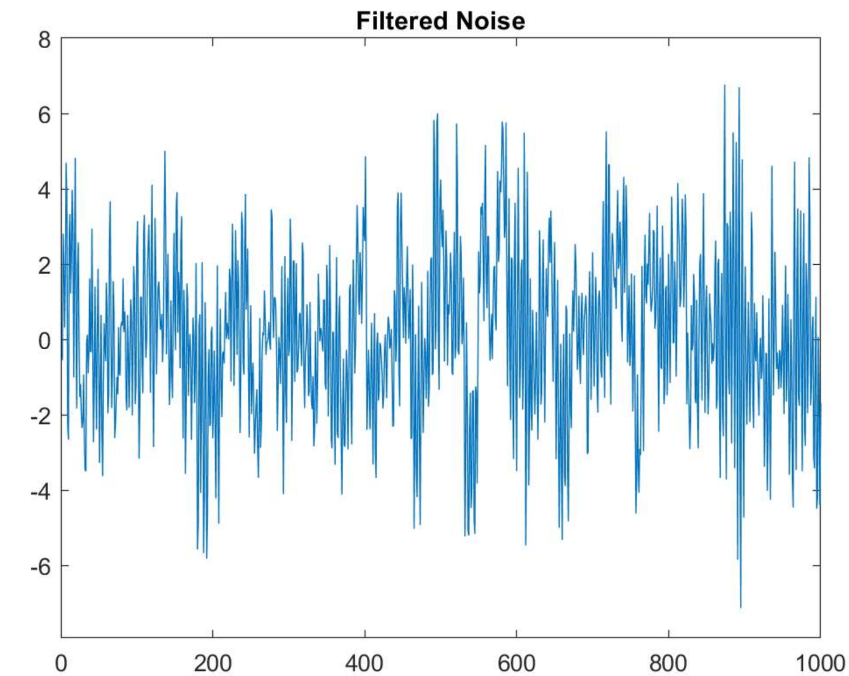
```
        sum(k) = sum(k) + a(i)*(z(k).^(-i)) ;
    end
end

H = 1./(1+sum)
psd2 = abs(H).^2
plot(f2, psd2)
```

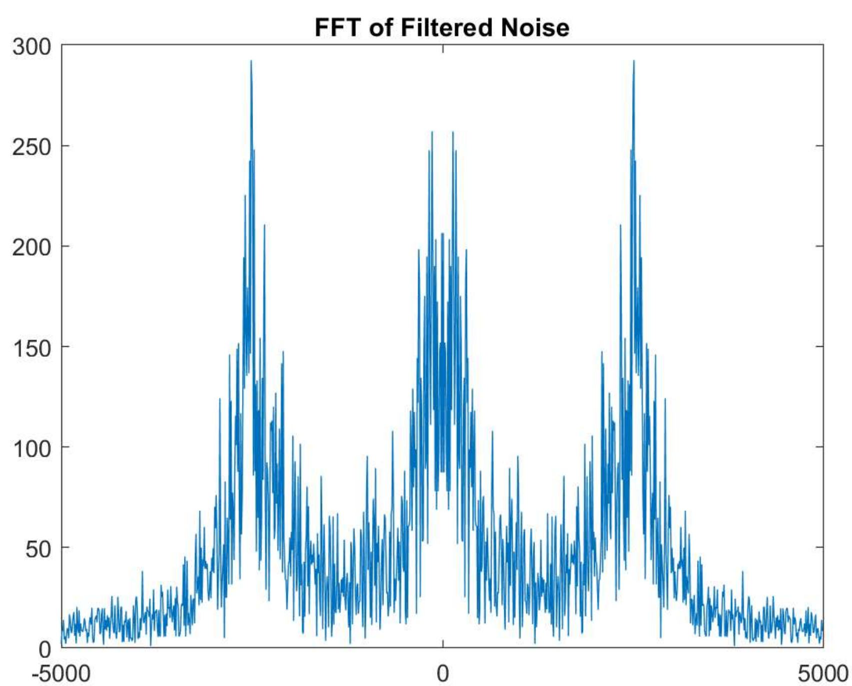
Plots

1. <u>Noise-</u>

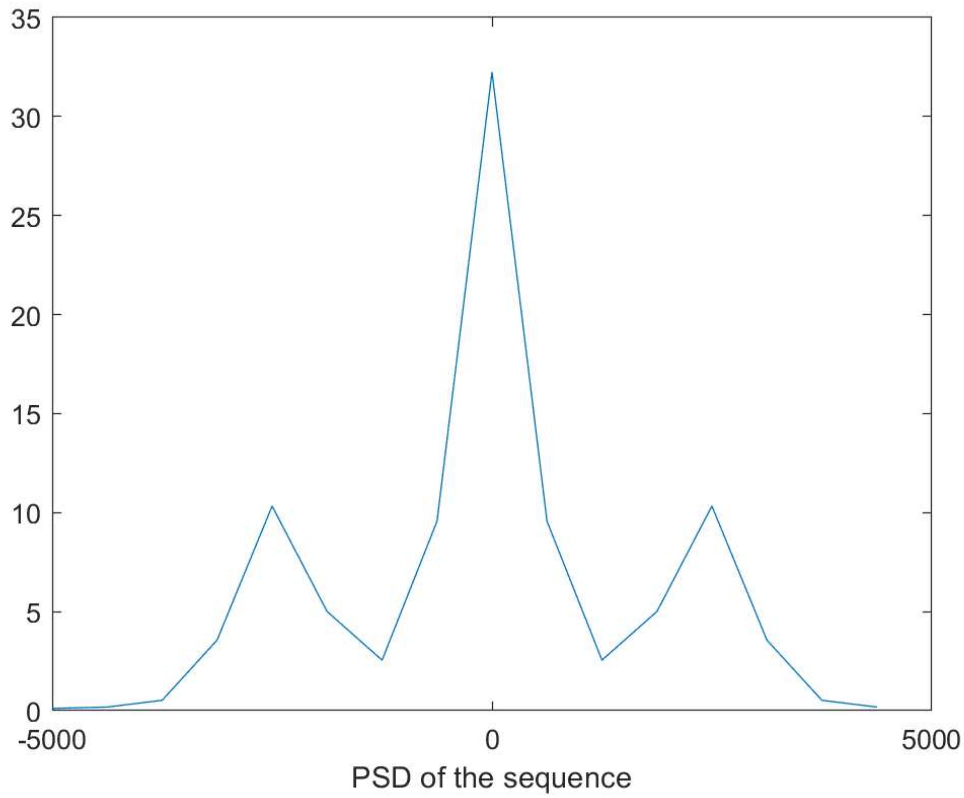


2. <u>Filtered Noise</u>-

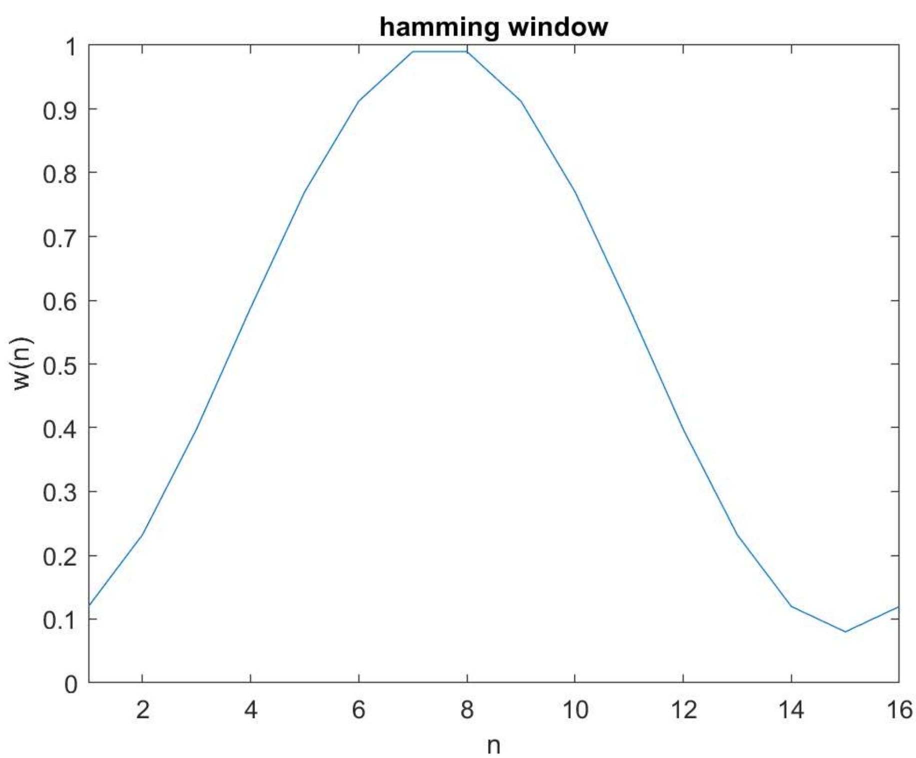




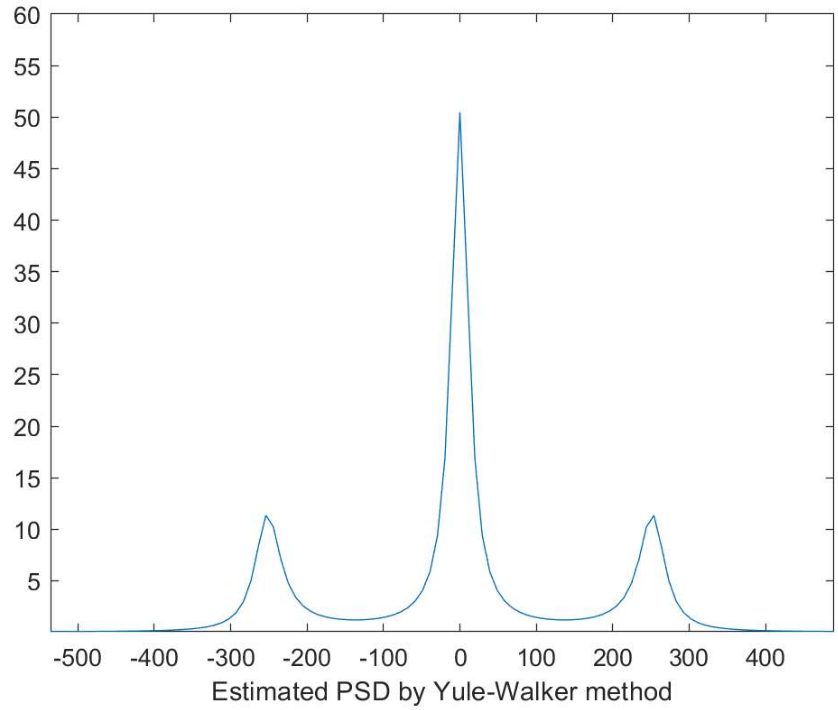
3. <u>Estimated PSD using the Welch Non-Parametric method</u>-



4. Hamming Window-



5. Estimated PSD by Yule-Walker method-



Discussion:

- In this experiment, we first create a sequence using gaussian noise with a defined variance and then pass it through the digital filter H(z). We can improve it by introducing overlap (let's say 50% in our case). Then the PSD of this sequence is obtained which is the theoretical PSD.

- In the next part of the experiment, we estimate the response of the digital filter H(z) which is defined by the coefficients 'ai'. To determine these coefficients, we have used the Yule-Walker AR model.

- Having obtained these parameters, the power spectrum of the sequence as well as the response of the digital filter can be estimated.

- The theoretical PSD and the estimated PSD both have the same number of peaks as the value of 'p'.As the number of points, N is increased the plots for PSD get smoother.

- We also observed that the parametric method(Yule-Walker) gives better estimation than the non-parametric method (Welch method).